Communications of the Association for Information Systems

Volume 37 Article 7

8-2015

Ontological Meta-Analysis and Synthesis

Arkalgud Ramaprasad
Department of Information and Decision Science, University of Illinois at Chicago, prasad@uic.edu

Thant Syn
Division of International Business and Technology Studies, Texas A&M International University

Recommended Citation
Ramaprasad, Arkalgud and Syn, Thant (2015) "Ontological Meta-Analysis and Synthesis," *Communications of the Association for Information Systems*: Vol. 37 , Article 7.
DOI: 10.17705/1CAIS.03707
Available at: https://aisel.aisnet.org/cais/vol37/iss1/7

Communications of the Association for Information Systems

Research Paper ISSN: 1529-3181

Ontological Meta-Analysis and Synthesis

Arkalgud Ramaprasad
Department of Information and Decision Science, University of Illinois at Chicago
prasad@uic.edu

Thant Syn
Division of International Business and Technology Studies, Texas A&M International University

Abstract:

We present ontological meta-analysis and synthesis as a method for reviewing, mapping, and visualizing the research literature in a domain cumulatively, logically, systematically, and systemically. The method highlights a domain's bright spots that have been heavily studied, the light spots that have been lightly studied, the blind spots that have been overlooked, and the blank spots that have not been studied. It highlights the biases in a domain's research; the research can then be realigned to make it stronger and more effective. We illustrate the method using the emerging domain of public health informatics (PHI). We present an ontological framework for the domain, map the literature onto the framework, and highlight its bright, light, and blind/blank spots. We also present detailed analyses using the ontological maps of dyads and triads. We conclude by discussing how (a) the results can be used to realign PHI research, and (b) the method can be used in other information systems domains.

Keywords: Ontological Meta-Analysis, Ontological Synthesis, Public Health Informatics.

The manuscript was received 28/03/2014 and was with the authors 3 months for 3 revisions.

1 Introduction

Reviewing and presenting diverse, contradictory, and heterogeneous research literature in an information system (IS) domain is challenging. Without a clear picture of the domain, one risks replaying the proverbial story of the five blind men each of whom imagined an elephant differently after touching its different parts. A sighted wise man helps them map these "parts" and visualize the whole elephant. Similarly, without a clear visualization of a research domain, the researchers in it may continue to fumble in the dark and leave the whole less than the sum of the parts. Accordingly the cumulative body of research may fail to resolve the problem it is intended to address. That is the challenge of mapping the research literature in a domain and visualizing it: the metaphorical domain "elephant" is neither fully known nor completely visible. It has to be made known and visible so that its parts can be mapped, the gaps can be seen, and the whole can be made strong (Platt, 1964), effective, and greater than the sum of the parts. An ontology can help fulfill this goal (Ramaprasad & Papagari, 2009).

Ontology is the study of being, which is in contrast to epistemology, which is the study of knowing. Ontology's focus is on objects, their categories, and the relationships between them—the nouns and verbs of the domain. Ontologies represent a domain's conceptualization (Gruber, 2008); they organize its terminologies and taxonomies. An ontology is an "explicit specification of a conceptualization" (Gruber, 1995, p. 908) It is used to systematically describe a complex system (Cimino, 2006). Moreover, as Quine (1961, p. 16) states:

> *Our acceptance of an ontology is… similar in principle to our acceptance of a scientific theory, say a system of physics; we adopt, at least insofar as we are reasonable, the simplest conceptual scheme into which the disordered fragments of raw experience can be fitted and arranged.*

In this paper, we argue that an ontology is a simple but powerful tool to meta-analyze and synthesize any research domain, including IS domains. Cumulative research is important and meta-analysis is an important method to synthesize it. However, meta-analysis is sometimes conducted in a very narrow sense to answer a specific question (e.g., do students learn more when class sizes are small?) or verify a specific aspect of a domain (Hunter & Schmidt, 1996). Our method is a holistic approach for surveying the landscape and assessing a domain's progress (e.g., are we moving in the right direction?) (Noar & Zimmerman, 2005).

An ontology may be induced from a domain's corpus. For this purpose, several automated ontology extraction tools based on linguistic extraction techniques such as part of speech (POS) tagging and natural language processing (NLP) exist (Alani et al., 2003). Based on the nouns and verbs in the corpus, the extraction techniques can help develop comprehensive and detailed (with reference to the corpus) OWL-based ontologies (W3C, 2012), thesauri of hierarchically arranged terms, and other ISO-based ontology exchange standards (Ahmad & Gillam, 2005). The automated tools are designed for standardizing terminologies (Burton-Jones, Storey, Sugumaran, & Ahluwalia, 2005; Evermann & Fang, 2010; Staab, Gómez-Pérez, Daelemana, Reinberger, & Noy, 2004), but not to deduce semantically meaningful logical components of a domain as we do. Automated tools cannot yet formulate an ontology that is (a) parsimonious as the one we propose, and (b) organized such that the domain components can be concatenated from it as natural language sentences.

The ontology we propose, on the other hand, is deduced from the domain's statement. It is based on Ramaprasad and Mitroff's framework (Ramaprasad, 1987; Ramaprasad & Mitroff, 1984) for formulating ill-structured problems; which is, in turn, based on the model proposed by Piaget (Piaget, 1974) for understanding causality. The ontology represents a domain's logic by structuring its components in the natural language of the domain. It too focuses on the key nouns and verbs (and sometimes adjectives) that define a domain and the relationship between them. However, instead of it being induced from the corpus, it is deduced from the domain's definition, applied to the domain's key documents, and modified iteratively until there is an acceptable fit. At this point, the ontology is attributed to the domain and the corpus is then mapped to the ontology. The details of the process of abstraction, application, and attribution are described in Ramaprasad and Mitroff (1984). Therefore, the ontology by itself is parsimonious and meaningful; it is not intended to be as comprehensive and detailed as the ones derived from automated tools. Because the ontology is deduced from a problem's statement, it may vary from one problem to another. In these ways, it is new and different from an induced ontology.

Computer scientists formally represent ontologies in the form of subject-predicate-object expressions which are known as triples. The ontology we use is a little more complex. We do not use the formal triples expression but rather deconstruct the problem into its basic dimensions and corresponding taxonomies incorporating the terminology of the domain. We organize the ontology's dimensions visually as a graphic table (Tufte, 1990) such that the concatenations across the dimensions (columns) form natural English sentences; each sentence describes a logical component of the domain, and the representation itself parsimoniously encapsulates the large number of logical components in it. The ontology is a complete, closed description of the domain, but one that is extensible and reducible: that is, more dimensions, categories, and subcategories can be added or deleted if necessary. The ontology's semantic interpretability and its components make it easy to validate and apply the ontology in practice. It helps make the problem known and visible in natural English. (It can be used with other languages, too, although the order of the columns would have to be changed to correspond to their sentence structure.)

We note that we present **an** ontology **not** the ontology: we recognize that there can be many equally valid ontologies for one domain. Each ontology is a lens to study a respective domain; each lens can offer a different insight about it. There may not be a universal ontology for the domain. The possibility of multiple ontologies is in the nature of the complex, ill-structured problems domains represent (Churchman, 1967; Ramaprasad & Mitroff, 1984). The "wicked" reality of domains calls for different perspectives (represented by corresponding ontologies) to bear in solving problems in them. The indefiniteness is not to avoid being logical, systematic, and systemic in conceptualizing a domain. It would be difficult, if not impossible, to assert a singular ontology to encapsulate a domain's complexity. It is the nature of the beast, unlike the metaphorical elephant, which has a singular physical identity.

Ontologies need to be valid, and we can judge their validity based on questions generated from earlier-stated definitions of an ontology: How explicit is the conceptualization? How logical is the conceptualization? How specific is the conceptualization? How systematic is the description? And how systemic is the description? Thus, in the context of a domain's ontology, one may ask: are the dimensions basic to the domain? Are the taxonomies basic to the dimensions? Are the concatenations basic to the domain? We address these questions using the constructs of face validity, content validity, systemic validity, and external validity, which are commonly used in social science research (Brennan, Voros, & Brady, 2011; Horn & Lee, 1989).

Ontological meta-analysis and synthesis provides a method and tools to continuously envision the "big picture" of an IS research domain. Such a picture can be viewed and analyzed interactively from different points of view and at different levels of granularity. The underlying ontology is itself scalable and extensible and can accommodate future developments in the field. Thus, a domain's roadmap can evolve in synchrony with emergent science, practice, and needs via continuous feedback (Ramaprasad, 1979, 1983; Ramaprasad & Syn, 2014) and learning.

We draw on the concept of ontologies to develop a framework to envision public health informatics (PHI), an emerging IS domain in healthcare. In Section 2, we present the derivation of an ontology for PHI and, in Section 3, discuss its validation. In Section 4, we present the method of mapping the current research on PHI onto the ontology. In Section 5, we present the visualizations and associated descriptions of monads, dyads, and select triads, and analyze them. Here we also discuss the bright, light, and blind/blank spots in PHI research, and present our interpretation of the meta-analysis and synthesis of PHI research. In Chapter 6, we conclude the paper by discussing the application of the method to other IS research domains. The PHI discussion draws heavily on Ramaprasad (2012).

2 Ontology of PHI

Figure 1 shows how we formulated the PHI ontology, which we did manually. We use an Excel spreadsheet to organize and present the ontology. Automated POS tagging and NLP tools that we mention in Section 1 operate on a different principle (induction and not deduction) than we applied and do not generate the type of ontologies we seek: those that are parsimonious and from which a domain's components can be articulated in natural language sentences and phrases. These properties are important to assure the applicability and validity of the ontology. They present a domain's "big picture" in a single view in an easily comprehensible and understandable way.

It may be some time before automated tools are developed to deduce such ontologies. However, our reliance on manually formulating our ontology should not detract from our method's validity and applicability. The ontology should be judged on its merits as a logical representation of the domain and not by the technique used for its formulation. In the future, there will likely be semi-automated and automated tools for deducing such ontologies using the same or similar methods.

Public health informatics (PHI) is a relatively new field that is still evolving. It has emerged from the increasing importance of managing information to ensure public health in managing, for example, disease epidemics, illness precursors such as obesity, and similar issues. PHI is the application of IS to public health. Logically, we can deconstruct it as: PHI = public health + informatics + stakeholders (the stakeholders are implied in the name). Figure 1 shows these dimensions graphically and we explain them below. Note that we capitalize the words used as names of dimensions, sub-dimensions, dimension categories, and sub-categories (except in sentences that describe the complete components of the ontology).

Informatics						Public Health				
Structure		**Function**		**Information**		**Function**		**Focus**		**Stakeholders**
Technology	[for]	Acquisition	[of]	Data	[to]	Plan for	[x]	Diseases & Conditions	[by]	Health Professionals
Hardware		Storage		Analyses/Statistics		Prepare for		Unhealthy Living		Federal/National
Software		Retrieval		Interpretations		Prevent		Hazards		State
Networks		Processing		Recommendations		Control		Injury, Violence & Safety		Local
Personnel		Distribution		Guidelines		Respond to		Environmental Illness		Territorial
Policies				Tools		Cope with		Workplace Danger & Illness		Tribal
Processes										Organizations
										Public
										Private
										General Population
										Individuals
										Families
										Communities

Illustrative Components of Public Health Informatics:

Technology for acquisition of data to respond to diseases & conditions by health professionals.
Networks for distribution of recommendations to prepare for hazards by general population.
Processes for storage of data to cope with workplace danger & illness by organizations.
Technology $_{\text{software}}$ for processing of analyses/statistics to control environmental illness by health professionals $_{\text{state}}$.

Figure 1. Ontology of Public Health Informatics (PHI)

Public Health can be further deconstructed into two sub-dimensions: its Function and Focus (Figure 1). Focus includes the objects of actions included in the Function. Thus, the Functions are the domain's key words; the Focuses are the key nouns. The Centers for Disease Control (CDC) is a (perhaps the) premier public health agency in the world in research, policy, and practice, and its articulation of the "public health" construct is, therefore, a strong basis for the ontology. Based on the CDC's external websites (CDC Foundation, 2014; Centers for Disease Control and Prevention, 2014), Public Health's Focus includes Diseases and Conditions, Unhealthy Living, Hazards, Injury, Violence, and Safety, Environmental Illness, and Workplace Danger and Illness. Its Function includes Plan for, Prepare for, Prevent, Control, Respond to, and Cope with. Thus, Public Health includes Plan for Diseases and Conditions, Cope with Workplace Danger and Illness, Prevent Hazards, and the 33 other possible combinations of Function and Focus. While the taxonomies of Function and Focus are not presented as such on the website, Figure 1 includes all the categories described therein. Their combinations cover, parsimoniously yet comprehensively, the connotation of Public Health according to the CDC.

The Functions are presented in the order they are usually considered, although they are likely to be iterative. Plan for precedes Prepare for, Prepare for precedes Prevent, and so on. Thus, there is a sequential logic underlying the dimension's construction. Should a function be not relevant in a particular context (e.g., another country) it may be eliminated, although this situation is unlikely. On the other hand, more likely, should a new function be deemed important (e.g., Assessment of, preceding Plan for or following Cope with), it could be added to the taxonomy. We do not include it because the CDC does not explicitly do so. Thus, the categories of Function are distinct (though not necessarily mutually exclusive due to likely overlaps), reasonably exhaustive, and ordered in their general temporal sequence. They are, however, not mutually exclusive, absolutely exhaustive, and perfectly ordered—natural language constructs as those embodied in the taxonomy of Functions (and others in the ontology) are not amenable to such an ideal construction.

The Focus categories can be considered to be nominally ordered; that is, there is no rationale for ordering them as they have been presented except to imitate the CDC. They are implicitly, perhaps, ordered by relative importance or frequency of occurrence, but there is no explicit evidence to that effect. It does not matter for the purpose at hand. Further, some of the categories are compound categories that cover multiple conditions: for example, the single category Injury, Violence, and Safety. They may be defined so because of the strong association between them and hence their co-occurrence. At a later time or in another context, it may be appropriate to disaggregate these compound categories. However, for now, we adhere to the CDC's use of these terms. They are distinct and can be said to be reasonably exhaustive.

We derived the Stakeholders taxonomy in Public Health in the same way as the Function and Focus taxonomies from the CDC's website. The taxonomy is presented at two levels. At the first level are three categories: Health Professionals, Organizations, and General Population. The second level includes the subcategories of each category. These categories too are distinct and reasonably exhaustive per the CDC's definitions.

Thus, combining Public Health Function and Focus with Stakeholders, we obtain combinations such as Plan for Diseases and Conditions by Health Professionals, Cope with Hazards by Organizations, and Control Unhealthy living by General Population Families. (Note that we use subscript to show subcategories.) There are 108 first-level and 360 second-level combinations of Public Health and Stakeholders. These 108/360 phrases can be said to logically define the Public Health domain based on the CDC's definitions.

Informatics can be deconstructed into its Structure, Function, and Information dimensions. Each of these PHI dimensions is defined by a corresponding taxonomy. The taxonomies of Informatics' Structure and Function dimensions are from the traditional literature in the field, from the common body of knowledge in any basic text book (e.g., Rainer & Cegielski, 2011). They are more or less standard. They can of course be extended by adding categories or refined by adding sub-categories. The standard is adequate for our purpose.

Informatics' Information dimension encapsulates both generation (first four categories) and application (last two categories) in the semiotic cycle (Ramaprasad & Rai, 1996). We have adapted their labels to the terminology of the public health domain. Thus, Data refers to morphologics, Analysis/Statistics to syntactics, Interpretations to semantics, and Recommendations to pragmatics. Guidelines are derived from recommendations and Tools are designed to translate the guidelines into action. We chose not to use the Data, Information, Knowledge, Wisdom taxonomy sometimes used in the literature because of its asymmetric focus on generation and not on application. The iteration of generation and application is critical for PHI because it is an applied domain.

Thus, Informatics' three illustrative components are Technology Hardware for Acquisition of Data, Networks for Distribution of Recommendations, and Policies for Storage of Guidelines. There are 150 first-level and 180 second-level combinations of Informatics. One can say that these 150/180 phrases logically define the domain of informatics in the context of PHI based on semiotics and the CDC's mandate.

The six dimensions arranged left to right, as in Figure 1, with the interleaved words constitutes PHI's ontology. It encapsulate 16,200 logical first-level components of PHI expressed in natural English, and 57,600 logical second-level components. Of these, four illustrative logical components are:

- Technology for acquisition of data to respond to diseases and conditions by health professionals (e.g., online data input system for data on influenza epidemic).
- Networks for distribution of recommendations to prepare for hazards by general population (e.g., social media networks for broadcasting emergency warnings).
- Processes for storage of data to cope with workplace danger and illness by organizations (e.g., formalized web-based processes for recording workplace accidents).
- Technology software for processing of analyses/statistics to control environmental illness by health professionals state (e.g., , data mining technology for analyzing the distribution of an unusual cancer in a region).

A logical component derived from the ontology may have many, a few, or no instantiations. Thus, in the above illustrations, there may be many Networks, a few Processes, and no Technology Software. Thus, the ontology encapsulates the core logic of a complex and varied PHI system, and all the instantiations of the components can be mapped to the ontology.

3 Validity of The Ontology

The ontology's validity determines how well it visualizes and represents the domain. Several authors have addressed the issues related to ontology validity and quality in the past (Burton-Jones et al., 2005; Evermann & Fang, 2010; Staab et al., 2004). However, they have focused on induced ontologies at a finer level of detail, greater formalism, and machine readability, and not on deduced ontologies such as the PHI ontology. We, by contrast, draw on the traditional constructs of validity and assert the framework's face, content, semantic, and systemic validity, and the external validation of the same by experts in the domain (Brennan et al., 2011; Horn & Lee, 1989).

The ontology is a complete closed description of a PHI system. Each logical component is semantically meaningful; thus, the face validity of the ontology is high. Its dimensions are well founded in the frameworks of IS and public health science, policy, and practice (as articulated by the CDC). The dimension taxonomies include all the basic categories. Thus, the content validity of the dimensions, the taxonomies, and the large number of consequent components is high.

All the logical components in the ontology may not be empirically instantiated. Even a single instantiation will indicate that it is a physical component of the domain. On the other hand, the interpretation of the non-instantiation of a logical component is equivocal. The non-instantiation may indicate an oversight or an infeasible component. If the former, it would be a blind spot of the domain. It would be a component that may have been overlooked inadvertently. If the combination is infeasible, it may be a truly blank spot in the domain. It is not possible to decide based on the present literature alone whether a non-instantiation is a blank or a blind spot. Hence, we refer to them equivocally as blank/blind spots. Thus, in summary, the ontology encapsulates all the possible components of a PHI system. It has high systemic validity.

We presented the framework to a group of experts in PHI at CDC and as a peer-reviewed poster in a professional conference on informatics (Ramaprasad, 2012). The affirmative comments in these forums further evidence the framework's validity. In Section 4, we map the current PHI literature onto the framework to determine the bright, light, and blind/blank spots therein.

4 Mapping The Current Research On PHI

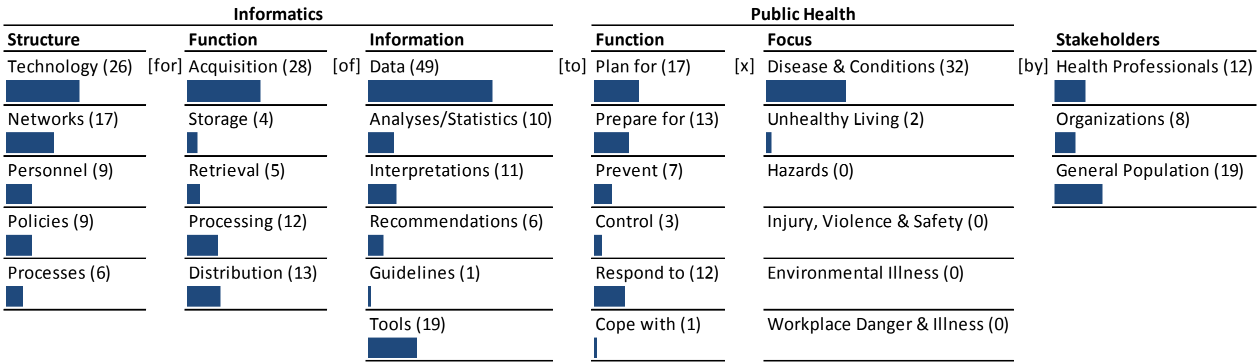
We systematically searched for all papers with PHI in the title, abstract, or source in the Web of Science and Google Scholar databases, and all abstracts in the Online Journal of Public Health Informatics as of January 2012. We found 84 papers, which represents the population of papers on the subject for the period, not just a sample. The number of papers is relatively few because PHI is a nascent domain. The small number of papers is convenient, but the method is scalable and can be extended to larger numbers. (We have subsequently worked on problems with almost ten times the number of papers. The advantage of ontological mapping is that it can map the population of papers on a topic, not just a sample.) By mapping the population of articles the method is sensitive to the strong signals of a large number of articles about a component as well as the weak signals of only a few. It highlights the body and the tails of the distribution of knowledge in the domain.

We downloaded the papers' abstracts to an EndNote library. From the EndNote library, we imported them into NVivo. In NVivo, we first created a hierarchical node structure with a node for each dimension and taxonomic category in the ontology. (We did not analyze the second level of taxonomies.) Second, we sequentially queried for each node/category and its synonym in the abstracts. Third, we manually evaluated each node/category synonym reference in the abstracts in its context. Fourth, based on the evaluation, we tagged the reference with its context to the corresponding node/category. When concluding the process, an abstract could be tagged for (1) one or many occurrences of a node/category (e.g., one or multiple references to Networks); (2) for one or many nodes/categories (e.g., references to Technology, Processing, Data, Control, and/or General Population); (3) both; or (4) none.

5 Analysis and Results

5.1 Ontological Map of PHI

We analyzed the data on the nodes/categories tagged in each abstract; we did not analyze the number of occurrences of a node/category in each abstract. Figure 2 shows the number of abstracts with reference to each node/category in the ontology in parentheses adjacent to the category. The bar below each category in the ontological map is proportional to the frequency and was generated automatically by an Excel-based visualization tool developed by one of the authors. Thus, it maps PHI monads—focused on each element of the ontology but not on combinations of these elements. The maps of dyads and select triads highlight the corresponding frequencies.



* Figures in parentheses indicate frequency of occurrence in the 84 articles; the length of the bars below is proportional to the frequency.

Figure 2. Ontological Map of Public Health Informatics

Figure 3 shows the frequency of all possible dyads in the ontology (in and between dimensions). The rows and columns of the figure correspond to the ontology. The entry in each cell is the frequency of occurrence of the dyad. Cells with higher frequencies are colored darker than those with lower frequencies to aid visualization. The darker lines separating the categories of each dimension aid the visual separation of intra-dimensional dyads and inter-dimensional dyads. The former indicate the co-occurrence of categories in a dimension and the latter of categories across dimensions.

		Structure					Function					Information						Function						Focus						Stake-holders		
		Technology	Networks	Personnel	Policies	Processes	Acquisition	Storage	Retrieval	Processing	Distribution	Data	Analyses/Statistics	Interpretations	Recommendations	Guidelines	Tools	Plan for	Prepare for	Prevent	Control	Respond to	Cope with	Disease & Conditions	Unhealthy Living	Hazards	Injury, Violence & Safety	Environmental Illness	Workplace Danger & Illness	Health Professionals	Organizations	General Population
Structure	Technology																															
	Networks	8																														
	Personnel	4	4																													
	Policies	4	4	2																												
	Processes	4	3	1	2																											
Function	Acquisition	9	10	2	3	4																										
	Storage	2	2	1	1	1	2																									
	Retrieval	1	2	1	2	1	4	3																								
	Processing	3	4	3	2		5																									
	Distribution	6	7	4	5	2	4	2	2	5																						
Information	Data	17	16	9	9	4	23	3	4	11	12																					
	Analyses/Statistics	5	3		1	2	6	1	2		3	7																				
	Interpretations	6	6	1	2	3	8	1	1	2	3	9	3																			
	Recommendations	3	2	1		1	3	1				4																				
	Guidelines			1		1	1					1			1																	
	Tools	8	10	4	5	3	8	1	2	3	6	17	3	4	1																	
Function	Plan for	7	3	3	3		7	1	2	4	4	13	4	3	1		2															
	Prepare for	7	5	2	2	1	7			3	5	9	2	3	2		5	2														
	Prevent	3	1	1		2	4	1				3		2	3	1	1															
	Control	3	2		1	2	1				1	2	1				1		1													
	Respond to	1	4	4	3	1	6	1	1	5	3	11		4	1	1	4	3	3	1												
	Cope with						1					1					1		1													
Focus	Disease & Conditions	14	8	5	5	3	20	1	2	8	7	24	4	6	3	1	9	7	8	5	1	7	1									
	Unhealthy Living	2	1		1	2	1				1	1		1			1			1	1			1								
	Hazards																															
	Injury, Violence & Safety																															
	Environmental Illness																															
	Workplace Danger & Illness																															
Stake-holders	Health Professionals	4	4	1	2	1	7		1	3	2	10	2	2	1		3	4	2	2				9								
	Organizations	6	3	2	1	2	1	1			1	5	1		3		5	2	2	1	2			2	1							
	General Population	7	7	2	3	2	12	2	2	5	3	15	2	4	1	1	10	4	4	3	1	5	1	13						3	2	

Highest Frequency (24) Zero Frequency

Figure 3. Ontological Map of Public Health Informatics Dyads

Extending the analysis, in Figure 4, we present the maps of three triads. The three are illustrative—17 other triad maps can be derived from the ontology. The first triad is of the three dimensions of Informatics, the second is of the two dimensions of Public Health and Stakeholders, and the third of the Informatics Function, Information, and Focus. It would be possible to analyze tetrads, pentads, and hexads (full components), but, for this paper, we do not do so. Monads, dyads, and triads are adequate to illustrate the method's value.

Structure-Function-Information

	Structure																								
	Technology					Networks					Personnel					Policies					Processes				
	I-Function					I-Function					I-Function					I-Function					I-Function				
Information	Acquisition	Storage	Retrieval	Processing	Distribution	Acquisition	Storage	Retrieval	Processing	Distribution	Acquisition	Storage	Retrieval	Processing	Distribution	Acquisition	Storage	Retrieval	Processing	Distribution	Acquisition	Storage	Retrieval	Processing	Distribution
Data	7	2	1	3	6	9	1	1	4	7	2	1	1	3	4	3	1	2	2	5	3	1	1		2
Analyses/Statistics	3	1	1		2	2	1	1		2						1	1	1		1	1	1	1		1
Interpretations	4	1	1	1	3	5	1	1	1	3				1	1	1	1	1	1	2	3	1	1		1
Recommendations	1	1				1					1										1				
Guidelines											1										1				
Tools	2	1	1	2	4	4	1	1	2	5				1	2	1	1	1	1	5	2	1	1		2

Public Health Function-Focus-Stakeholders

	Public Health-Function																																			
	Plan for						Prepare for						Prevent						Control						Respond to						Cope with					
	Focus						Focus						Focus						Focus						Focus						Focus					
Stakeholders	Disease & Conditions	Unhealthy Living	Hazards	Injury, Violence & Safety	Environmental Illness	Workplace Danger & Illness	Disease & Conditions	Unhealthy Living	Hazards	Injury, Violence & Safety	Environmental Illness	Workplace Danger & Illness	Disease & Conditions	Unhealthy Living	Hazards	Injury, Violence & Safety	Environmental Illness	Workplace Danger & Illness	Disease & Conditions	Unhealthy Living	Hazards	Injury, Violence & Safety	Environmental Illness	Workplace Danger & Illness	Disease & Conditions	Unhealthy Living	Hazards	Injury, Violence & Safety	Environmental Illness	Workplace Danger & Illness	Disease & Conditions	Unhealthy Living	Hazards	Injury, Violence & Safety	Environmental Illness	Workplace Danger & Illness
Health Professionals	3						2						2						2						2											
Organizations	1						1						1						1						1											
General Population	3						3						3						3						3						1					

Informatics Function-Information-Focus

	Informatics-Function																													
	Acquisition						Storage						Retrieval						Processing						Distribution					
	Information						Information						Information						Information						Information					
Focus	Data	Analyses/Statistics	Interpretations	Recommendations	Guidelines	Tools	Data	Analyses/Statistics	Interpretations	Recommendations	Guidelines	Tools	Data	Analyses/Statistics	Interpretations	Recommendations	Guidelines	Tools	Data	Analyses/Statistics	Interpretations	Recommendations	Guidelines	Tools	Data	Analyses/Statistics	Interpretations	Recommendations	Guidelines	Tools
Disease & Conditions	16	4	5	3	1	5	1	1	1			1	2	1	1			1	7		1			2	6	3	3			3
Unhealthy Living			1																						1					1
Hazards																														
Injury, Violence & Safety																														
Environmental Illness																														
Workplace Danger & Illness																														

Highest Triad Frequency (16)   Zero Frequency

Figure 4. Ontological Map of Select Public Health Informatics Triads

5.2 PHI Node Clusters

We also performed a cluster analysis in NVivo as an alternative method to identify bright, light, and blind/blank spots. NVivo features three clustering techniques based on the Pearson correlation coefficient, Jaccard's coefficient, and Sørensen's coefficient (QSR International, 2014). We chose our technique based on the purpose of our analysis (primarily descriptive and exploratory, not explanatory or confirmatory), the nature of the data (nominal), and convenience (readily available in NVivo). We generated the PHI clusters based on the similarity of categories (nodes in NVivo) measured by Jaccard's coefficient or index. Jaccard's coefficient is commonly used to measure the similarity between two groups or sets depending on the co-occurrence of certain values or quantities (Jaccard, 1912; Lee, 1999; Levandowsky & Winter, 1971; Rahel, 2000). In NVivo, the coefficients are computed on the coding similarity between any given pair of nodes where the primary measure of similarity is nominal (1 if two nodes are both coded to a given source, 0 if not) (QSR International, 2014). Jaccard's coefficient is then computed as the ratio of the number of times two nodes are coded together to the number of times either node is coded. NVivo generates a table of coefficients used in generating clusters; Figure 5 shows the highest 25 coefficients.

Node A	Node B	Jaccard's coefficient
Nodes\\2 I-Function\2.3 Retrieval	Nodes\\2 I-Function\2.2 Storage	0.5
Nodes\\5 PH-Focus\5.1 Diseases & Conditions	Nodes\\2 I-Function\2.1 Acquisition-Surveillance	0.463415
Nodes\\3 Information\3.1 Data	Nodes\\2 I-Function\2.1 Acquisition-Surveillance	0.425926
Nodes\\5 PH-Focus\5.1 Diseases & Conditions	Nodes\\3 Information\3.1 Data	0.421053
Nodes\\3 Information\3.6 Tools	Nodes\\1 I-Structure\1.2 Networks	0.384615
Nodes\\6 Stakeholders\6.3 General Population	Nodes\\2 I-Function\2.1 Acquisition-Surveillance	0.342857
Nodes\\3 Information\3.6 Tools	Nodes\\3 Information\3.1 Data	0.333333
Nodes\\5 PH-Focus\5.2 Unhealthy Living	Nodes\\1 I-Structure\1.5 Personnel	0.333333
Nodes\\3 Information\3.1 Data	Nodes\\1 I-Structure\1.2 Networks	0.32
Nodes\\5 PH-Focus\5.1 Diseases & Conditions	Nodes\\1 I-Structure\1.1 Technology	0.318182
Nodes\\6 Stakeholders\6.3 General Population	Nodes\\3 Information\3.6 Tools	0.310345
Nodes\\6 Stakeholders\6.3 General Population	Nodes\\5 PH-Focus\5.1 Diseases & Conditions	0.307692
Nodes\\2 I-Function\2.5 Distribution	Nodes\\1 I-Structure\1.2 Networks	0.304348
Nodes\\4 PH-Function\4.3 Prevent	Nodes\\3 Information\3.4 Recommendations	0.3
Nodes\\2 I-Function\2.5 Distribution	Nodes\\1 I-Structure\1.4 Policies	0.294118
Nodes\\3 Information\3.1 Data	Nodes\\1 I-Structure\1.1 Technology	0.293103
Nodes\\2 I-Function\2.1 Acquisition-Surveillance	Nodes\\1 I-Structure\1.2 Networks	0.285714
Nodes\\4 PH-Function\4.4 Respond to	Nodes\\1 I-Structure\1.5 Personnel	0.285714
Nodes\\6 Stakeholders\6.3 General Population	Nodes\\3 Information\3.1 Data	0.283019
Nodes\\3 Information\3.3 Interpretations	Nodes\\1 I-Structure\1.2 Networks	0.272727
Nodes\\6 Stakeholders\6.2 Organizations	Nodes\\3 Information\3.4 Recommendations	0.272727
Nodes\\4 PH-Function\4.5 Control	Nodes\\2 I-Function\2.4 Processing	0.263158
Nodes\\3 Information\3.3 Interpretations	Nodes\\2 I-Function\2.1 Acquisition-Surveillance	0.258065
Nodes\\6 Stakeholders\6.1 Health Professionals	Nodes\\5 PH-Focus\5.1 Diseases & Conditions	0.257143
Nodes\\2 I-Function\2.5 Distribution	Nodes\\2 I-Function\2.4 Processing	0.25

Figure 5. Jaccard's Coefficients for Top 25 Pairs of Nodes

Figure 6 shows the resultant clusters. Among the frequently occurring nodes, there appears to be three clusters representing the following themes: (1) Technology and Networks for Acquisition/Surveillance of Data, Interpretations, and Tools to Prepare for Diseases and Conditions; (2) Processes and Policies for Processing and Distribution (of Information) to Control (Diseases and Conditions); and (3) Analysis/Statistics to Plan for (Diseases and Conditions) by Health Professionals. The other clusters of infrequently occurring nodes cannot be meaningfully interpreted.

In the future, coding data from NVivo may be exported to other statistical analysis tools such as SPSS and SAS. Additional clustering techniques and distance measures available in these tools may yield additional insights about the domain.

5.3 Bright, Light, Blind/Blank Spots in PHI

There is a wide variation in the emphasis on the different categories in the ontology in the PHI literature. Among monads, the highest emphasis is on Data (49), Diseases and Conditions (32), Acquisition (28), and Technology (26): these are the bright spots. There is no consideration of Hazards, Injury Violence and Safety, Environmental Illness, and Workplace Danger and Illness: these are blind/blank spots, most likely blind spots for all these categories are central to PHI. Personnel (9), Policies (9), Processes (6), Storage (4), Retrieval (5) and the like are the light spots. The distinction between the three categories is subjective, based on significant breaks in the frequency distribution. Reading across the dimensions of the ontology one could conjecture that (1) Technology/Networks for Acquisition of Data to Plan for/Prepare for/Respond to Diseases and Conditions by the General Population/Health Professionals is a dominant theme in the PHI literature; but (2) Guidelines to Control/Cope with Hazards/Injury, Violence and Safety/Environmental Illness/Workplace Danger and Illness is virtually non-existent. The cluster analysis results reinforce the labeling of the categories as bright, light, blind/blank spots. The blind/blank spots form the outlying clusters outside the three core clusters labeled in Figure 6.

Our above conjectures based on the analysis of monads can be refined by studying the dyads and triads. If the high frequency categories of Data (49), Diseases and Conditions (32), Acquisition (28), and Technology (26) occur frequently in combinations with each other, the frequency of the corresponding dyads and triads will be high. On the other hand, if they occur in combination with other categories, the frequency of the corresponding dyads and triads will be low. The highest frequency dyads (Figure 3) in descending order are Diseases and Conditions–Data (24), Data–Acquisition (23), and Diseases and Conditions–Acquisition (20). The next three are Data–Technology (17), Tools–Data (17), and Data–Networks (16). These dyads reinforce the conjecture of the relationships among the bright monads, but with the addition of two light monads: Tools and Networks. Logically, a blind/blank monad cannot be part of a dyad. Figure 3 highlights the bright, light, and blind/blank dyads.

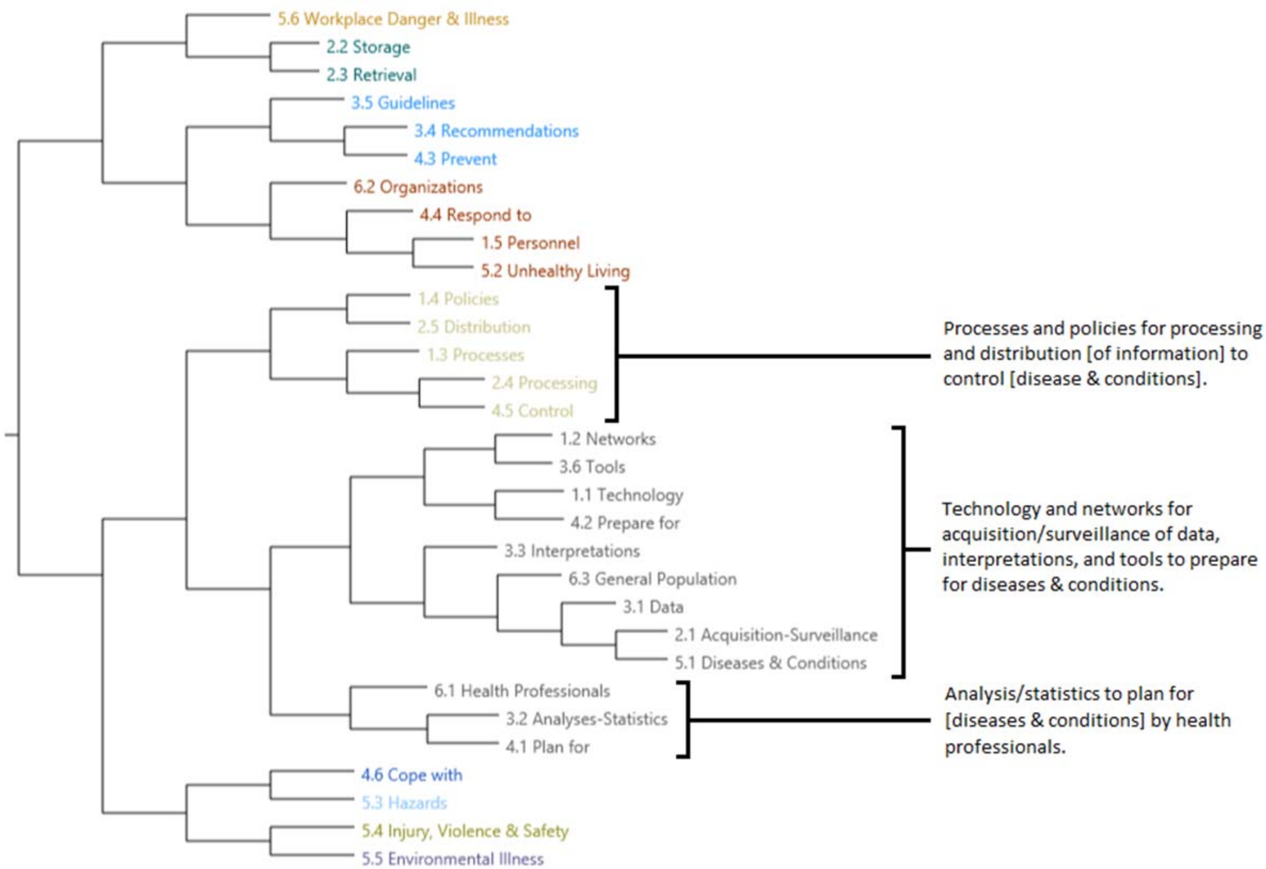


Figure 6. Jaccard's Coefficients for Top 25 Pairs of Nodes

The triad maps are sparse. Among all the triads (shown in Figure 4 and not shown in the paper) Diseases and Conditions–Data–Acquisition (16) has the highest frequency. It is a triad of three bright monads. Other notable triads among those shown are Data–Acquisition–Networks (9), Data–Acquisition–Technology (7), Data–Distribution–Networks (7), and Diseases and Conditions–Data–Processing (7). These are combinations of bright and light monads. Logically, a blind/blank monad cannot be part of a triad. We do not list all the triads in order of their occurrence, but Figure 4 highlights the bright, light, and blank/spots among the selected set of triads.

5.4 Interpretation

The ontological maps of the PHI literature (Figures 2, 3, and 4) have a few bright spots that are heavily emphasized, more light spots that are less emphasized, and many blind/blank spots that are hardly or never mentioned. There are many potential explanations for the unevenness of coverage.

First, the ontology may be specified incorrectly. We believe this is unlikely. The dimensions and the taxonomies of the ontology have been derived logically from the extant frameworks for informatics and public health. There are alternative ways of structuring the framework—the structure presented in Figure 1 is one of many. It has high face validity, content validity, and systemic validity. While there may be errors of omission and commission in the details of the taxonomies, one can argue that, overall, it is a valid, logical framework of PHI, with an emphasis on the “a”. With wicked problems (Churchman, 1967), one cannot assert a singular ontological representation.

Second, the sample of abstracts may be incomplete. This is more likely than the first explanation. This may be due to the exclusion of papers not specifically referring to PHI but which may in fact belong to the domain. This is particularly likely because PHI is an emerging field and many relevant papers may not allude to it explicitly.

Third, the bright, light, and blind/blank spots reflect the gaps in the state-of-the-research due to many factors such as:

- Funding that skews toward the bright spots and away from the blank/blind spots
- Perceived state-of-the-need that bias attention towards the bright spots and away from the blank/blind spots
- Research priorities that focus on the bright spots and not on the blind/blank spots
- Research opportunism/fads that amplify the focus on the bright spots and away from the blind/blank spots
- Reinforcement of herd effect that amplifies the focus on the bright spots and lack of the same on the blind/blank spots, and
- The early stage of PHI’s development, which results in a narrow initial focus biased by history.

Funding is an important driver of research. Research priorities are often determined by the funding agencies’ assessment of the domain’s state-of-the-need and history. More often than not, there is an emphasis on continuity with the past with the expectation that past priorities were justified and more of the same will yield desired results. This is further reinforced by funding decision makers’ bias, whether conscious or unconscious, because of their own experiences and world-views. Occasionally, a dramatic event compels a break from the past and the realignment of priorities. PHI’s origins are in epidemiology, and the ontological map reflects this historical bias. Although PHI’s other components are recognized in the literature, there does not appear to have been a dramatic event to broaden PHI’s emphasis.

Research, like funding, too has its own inertia. It is easier to conduct research on well-worn topics: the methods are formalized and the topics are well known. Such research is also easier and quicker to publish compared to research using new methods and on novel topics: the reviewers are familiar with it, the gatekeepers are likely to accept it. They are seen as better opportunities for publication, with greater certainty and shorter turnaround times. These dynamics amplify the emphasis on the bright spots and away from the blind/blank spots.

Sometimes, funding and research are driven by fads whereby a surge of funding for and research on a new topic (which is suddenly seen as a panacea for an imminent problem) occurs. Such opportunism creates a herd mentality that reinforces attention on a few bright spots and ignores the light and blind/bright spots. The fad may be short lived or continued beyond the point of meaningful return due the dynamics of funding and publication inertia discussed in the previous paragraphs.

Last, the ontological map may simply be a reflection of the field's developmental stage. In early stages, it is likely to be sparse and history driven. It is only through a long-term, ongoing process of feedback and learning that its emphases can be balanced to reflect current needs. Moreover, since the field is in its early stages, the domain's thought leaders and the gatekeepers (in funding agencies and journal editorial boards) may not have had the opportunity to contemplate its "big picture".

We believe that a combination of these is the most likely explanation. While the literature coverage need not be uniform across the 16,200 possible logical components, the ontological maps (Figures 2, 3, and 4) and the dominant themes (Figure 6) reflect significant lacunae in the PHI research. There has to be a better balance for PHI to be effective as a field; the origins and consequences of these gaps have to be analyzed. We have to systematically examine whether the current bright spots are the right ones. Should there be more or less? Similarly, should there be other light spots and blank spots? While our method raises these questions, it is beyond our purview here to try to answer them. However, it can provide the type of feedback necessary for learning about the field, its strengths and weaknesses, and the gaps that need to be amplified or attenuated to address the problems the field intends to address.

Thus, for each spot—whether it is bright, light, or blind/blank—there can be two opposing interpretations. A bright spot may be so because it is important. On the other hand, a light spot may be rightly because it is not important. But a spot's brightness/lightness may also be a consequence of the sociology of funding and research, and of history with little relation to its actual value in addressing PHI's problems. Similarly, an empty spot, which may be a blind or a blank spot, may reflect an opportunity for innovation or be an indicator to exclude it from further consideration. While the ontological map highlights the gaps, the interpretation of the gaps is not self-evident. How the gap is interpreted and the equivocalities resolved will determine the consequent action; that is, whether a bright spot is brightened or dimmed, a light spot is brightened or blanked, or a blind spot is lightened or deemed a blank spot.

6 Conclusion and Implications: Ontological Meta-Analysis and Synthesis

We present ontological meta-analysis and synthesis as a method of addressing the challenge of reviewing and presenting diverse, contradictory, and heterogeneous research literature in an information system (IS) domain. One way of addressing the large, complex, and ill-structured problem is to synthesize and clearly visualize the domain in question—to make the proverbial "elephant" visible. We have illustrated the method with public health informatics (PHI), an emerging domain in healthcare informatics and more broadly in IS. We logically deconstruct the connotation of PHI into the dimensions of the ontology and define each dimension using taxonomies based on extant literature and practice. Thus, we develop a complete, closed description of PHI—a description that concisely encapsulates a large number (16,200 first-level, 51,600 second-level) of PHI's logical components. Each of these components can be stated in natural English and is meaningful to both the novice and the expert in the domain; it enhances the face and semantic validity (Kotis & Vouros, 2006) of the framework. We also discuss the framework's content and systemic validity, which we validated by presenting it to a group of experts. We mapped the extant literature on PHI onto the framework. We present the results as four visualizations: (1) select ontological maps of monads, dyads, and triads, and (2) a cluster diagram. These visualizations clearly highlight the bright, light, and blank/blind spots in the literature. We also discuss the potential explanations for the present visual topography of the literature. We conclude that the ontological meta-analysis and synthesis can be used to envision PHI systemically and systematically.

As we emphasize earlier, an ontology is one lens through which one can study the PHI domain. There can be other equally valid lenses. Each lens will likely yield a different visual topography and, thus, different insights into the bright, light, and blank/blind spots. Each of these sets of insights will be a product of observing the phenomenon systematically through a systemic framework—of a different way of making the "elephant" visible. Reconciling these differences, in addition to changing the visual topography of each by addressing the bright, light, and blank/blind spots, will advance knowledge in the domain and can set its research agenda.

While we chose PHI to illustrate how to apply the ontological meta-analysis and synthesis, the method can be applied to other domains of IS and other fields. The method is plastic and can be adapted to a wide range of fields in IS (and outside). It has been used to conceptualize eHealth, the role of informatics in clinical and translational science, and the concept of ubiquitous learning (Ramaprasad, 2009; Ramaprasad, Papagari, & Keeler, 2009; Ramaprasad, Valenta, & Brooks, 2008, 2009; Valenta, Brooks, Laureto, & Ramaprasad, 2007). For a long time, complex, ill-structured problems such as the one of defining a field's domain have been called "wicked" problems (Churchman, 1967), and they have been perceived as intractable. There is no one formulation of these problems: their formulation can vary depending on the formulator's vantage point. These different points of view can be parsimoniously encapsulated in ontologies and examined systematically and systemically—the frameworks serve as a logico-mathematical structures for the problem (Ramaprasad, 1987; Ramaprasad & Mitroff, 1984). Each ontology is a complete, closed, explicit description of the problem, and there can be multiple such descriptions.

6.1 Literature as Data

The literature in a chosen domain is the data for ontological meta-analysis and synthesis. Literature has always been used as data in reviewing past research in a domain and developing the conceptual framework for research. Such a review has traditionally been selective, informal, qualitative, and subjective. Contemporary tools for searching and analyzing text allow one to be exhaustive and formal in reviewing the literature and in quantifying the results. It can be objective as we show with the PHI literature. Using the ontology to analyze literature as data explicates the underlying logic of the domain and makes the assumptions and the results available for public discussion and debate. The ease of manipulating the framework and the availability of tools for searching and analyzing text also permit researchers to easily test the results when changing the assumptions/framework. The literature review becomes a literature synthesis through a specific lens.

The ability to explicate the data (literature), the ontology, and the data's encoding makes the method replicable and repeatable. While the process we used was semi-automated (the search was electronic, actual coding was semi-automatic using NVivo, and the visualization was automated), with the advances in text-mining tools, the entire process could be automated. In the future, given an ontology, it should be possible to automate analyzing literature in a domain. The process of automating the discovery of the ontology itself is likely to take longer. While there are tools for extracting ontologies and while they can be used for initial explorations, we have not found any tool that can extract ontologies that are semantically valid (the components have to be natural language sentences) and parsimonious (which fit an 8.5"x11" sheet of paper in a legible font). The present semi-automation and potential automation also makes the method scalable. It can handle "big text data" that comprises hundreds of papers.

The ontology is extensible and reducible, and, hence, the method is adaptable to the developments in a domain. Should a new Function or Focus of Public Health emerge in the future, for example, it can be added to the framework. Or, should a new subcategory of Health Professionals becomes a key Stakeholder, the ontology can be extended to accommodate the change. By the same token, if a category becomes irrelevant, it could be eliminated from consideration. The extensibility and reducibility will also help researchers trace the constructs' evolution in, and the logic of, the domain.

Last, visualization is key to making sense of and interpreting "big text data". The ontology provides an easy and intuitively understandable vehicle for visualization as we have shown with PHI. We are in the process of developing other visualizations. Note, for example, that the ontological maps (Figure 2) can be used to study a domain's evolution over time by creating maps for different cross-sections of time. It can also be used to study the map at different levels of granularity if the taxonomies have multiple levels and the data are coded accordingly. (Although the Stakeholders taxonomy in the PHI ontology has two levels, we did not code the data at the more detailed level.) The data also is amenable to other visualization tools such as cluster analysis (see Figure 6).

Limitations

There are many limitations to the method. While the semantic interpretability of natural English components benefits the ontology, the semantic variation in the interpretation of the components can be a limitation. A well-developed glossary of the terms in the ontology can reduce the variation but cannot eliminate it. The semantic variation can make the ontological maps noisy.

By the same token, while we argue that the compactness, comprehensiveness, and completeness of an ontology are advantages, they could also be seen as a limitation. These very characteristics could overwhelm linear thinkers' cognition (as opposed to systemic thinkers). Sequentially considering each of the thousands of logical components in the ontology, as linear thinkers are wont to do, can be overwhelming; they have to be processed simultaneously as a pattern as systemic thinkers do. For this reason, a novice who is more likely to think linearly than an expert may find the method daunting, whereas an expert adept at pattern processing may find it enlightening.

In the same vein, the advantage of visualization may be a disadvantage for non-visual and possibly narrative-based analysts. Non-visual analysts may not see the implications of the bright, light, blind/blank spots and deduce their implications. For those to whom the visualization is not intuitively meaningful, it will have to be explained, r alternative visualizations developed. Elaborating the thousands of logical components as a narrative would not only be voluminous but also undermine the method's central purpose.

It would be difficult to assert, based on the present research, definite reasons for the bright, light, and blind/blank spots; it would be even more difficult to recommend specific corrective actions. The two would require their own programs of research. We can, at best, present possible explanations that, together with the ontological analysis and synthesis, can be the starting point for these programs of research. The ontological maps, it must be noted, are based on the population of the papers during the time period of study and, therefore, present a definitive map of PHI research. The technique we propose is designed to help formulate problems (in this case of PHI) in such a way that it leads to more effective solutions. It is not intended to discover the underlying mechanisms or the potential solutions, but it can direct the search for underlying mechanisms and potential solutions, systemically and systematically. Mapping the topography of an important domain can itself be a significant contribution even if the topographer cannot definitively explain the reasons for the hills, plains, and valleys in it.

In sum, ontological meta-analysis and synthesis can be an effective and efficient vehicle for developing cumulative research in information systems. It can help researchers more comprehensively, visibly, and objectively summarize and synthesize. It can help researchers logically, quantitatively, systematically, and systemically analyze literature data. It can help researchers map the visual landscape of domains and their evolution over time. Most important, it can highlight a domain's bright, light, and blank/blind spots. A bright spot may not be the most important—it may be the easiest to research or a consequence of herd mentality. A blank spot may not be the least important—it may be a blind spot, important but overlooked because of the difficulty of investigation or, again, because of herd mentality. Resolving the equivocality of the blank/blind spot would require a researcher to literally think outside the box and could lead to significant advances in a respective domain. It can help the domain disengage from "more-of-the-same" research and lead to more "disruptive" research. The ontology can serve as a structured brainstorming tool for the researchers in a domain.

References

Ahmad, K., & Gillam, L. (2005). Automatic ontology extraction from unstructured texts. On the move to meaningful Internet systems 2005: CoopIS, DOA, and ODBASE (pp. 1330-1346). Springer.

Alani, H., Kim, S., Millard, D. E., Weal, M. J., Hall, W., Lewis, P. H., & Shadbolt, N. R. (2003). Automatic ontology-based knowledge extraction from web documents. Intelligent Systems, IEEE, 18(1), 14-21.

Brennan, L., Voros, J., & Brady, E. (2011). Paradigms at play and implications for validity in social marketing research. Journal of Social Marketing, 1(2), 3-3.

Burton-Jones, A., Storey, V. C., Sugumaran, V., & Ahluwalia, P. (2005). A semiotic metrics suite for assessing the quality of ontologies. Data & Knowledge Engineering, 55(1), 84-102.

CDC Foundation. (2014). What is public health? Retrieved September 28, 2014, from http://www.cdcfoundation.org/content/what-public-health

Centers for Disease Control and Prevention. (2014). Home page. Retrieved September 28, 2014, from http://www.cdc.gov/

Churchman, C. W. (1967). Wicked problems. Management Science, 14(4), B-141-142.

Cimino, J. J. (2006). In defense of the Desiderata. Journal of Biomedical Informatics, 39(3), 299-306.

Evermann, J., & Fang, J. (2010). Evaluating ontologies: Towards a cognitive measure of quality. Information Systems, 35(4), 391-403.

Gruber, T. R. (1995). Toward principles for the design of ontologies used for knowledge sharing. International Journal Human-Computer Studies, 43(5-6), 907-928.

Gruber, T. R. (2008). Ontology. In L. Liu & M. T. Ozsu (Eds.), Encyclopedia of database systems. Düsseldorg: Springer-Verlag.

Horn, B. R., & Lee, I. H. (1989). Toward integrated interdisciplinary information and communication sciences: A general systems perspective. Proceedings of the Hawaii International Conference on System Sciences, 4, 244-255.

Hunter, J. E., & Schmidt, F. L. (1996). Cumulative research knowledge and social policy formulation: The critical role of meta-analysis. Psychology, Public Policy, and Law, 2(2), 324-347.

Jaccard, P. (1912). The distribution of the flora in the alpine zone. New phytologist, 11(2), 37-50.

Kotis, K., & Vouros, G. (2006)/ Human-centered ontology engineering: The HCOME methodology/ Knowledge and Information Systems, 10(1), 109-131.

Lee, L. (1999). Measures of distributional similarity. Paper presented at the Proceedings of the 37th Annual Meeting of the Association for Computational Linguistics on Computational Linguistics.

Levandowsky, M., & Winter, D. (1971). Distance between sets. Nature, 234(5323), 34-35.

Noar, S. M., & Zimmerman, R. S. (2005). Health behavior theory and cumulative knowledge regarding health behaviors: Are we moving in the right direction? Health Education Research, 20(3), 275-290.

Piaget, J. (1974). Understanding causality. New York: Norton.

Platt, J. R. (1964). Strong inference. Science, 146(3642), 347-353.

QSR International. (2014). How are cluster analysis diagrams generated? Retrieved December 4, 2014, from http://help-nv10.qsrinternational.com/desktop/deep_concepts/how_are_cluster_analysis_diagrams_generated_.htm

Quine, W. V. O. (1961). From a logical point of view (2nd ed.). Boston, MA: Harvard University Press.

Rahel, F. J. (2000). Homogenization of fish faunas across the United States. Science, 288(5467), 854-856.

Rainer, R. K., & Cegielski, C. G. (2011). Introduction to information systems: Supporting and transforming business. New York: John Wiley & Sons.

Ramaprasad, A. (1979). Role of feedback in organizational-change—review and redefinition. Cybernetica, 22(2), 105-113.

Ramaprasad, A. (1983). On the definition of feedback. Behavioral Science, 28(1), 4-13.

Ramaprasad, A. (1987). Cognitive process as a basis for MIS and DSS design. Management Science, 33(2), 139-148.

Ramaprasad, A. (2009). Ubiquitous learning: An ontology. Ubiquitous Learning: An International Journal, 1(1), 57-65.

Ramaprasad, A. (2012). Envisioning public health informatics (PHI): A current ontological profile. AMIA 2012 Annual Symposium Proceedings (pp. 1909). Retrieved from http://ssrn.com/abstract=2173025

Ramaprasad, A., & Mitroff, I. I. (1984). On formulating strategic problems. Academy of Management Review, 9(4), 597-605.

Ramaprasad, A., & Papagari, S. S. (2009). Ontological design. In Proceedings of DESRIST 2009.

Ramaprasad, A., & Rai, A. (1996). Envisioning management of information. Omega-International Journal of Management Science, 24(2), 179-193.

Ramaprasad, A., & Syn, T. (2014). Strong and meaningful use of healthcare information systems (HIS). In M. Bienkiewicz, C. Verdier, G. Plantier, T. Schultz, A. Fred, & H. Gamboa (Eds.), Proceedings of HEALTHINF 2014—International Conference on Health Informatics. Angers, France: SCITEPRESS.

Ramaprasad, A., Papagari, S. S., & Keeler, J. (2009). eHealth: Transporting information to transform health care. In L. Azevedo & A. R. Londral (Eds.), Proceedings of HEALTHINF 2009—Second International Conference on Health Informatics (pp. 344-350). Porto, Portugal: INSTICC Press.

Ramaprasad, A., Valenta, A., & Brooks, I. (2008). Clinical and translational science informatics: A framework and case study. In L. Azevedo & A. R. Londral (Eds.), Proceedings of HEALTHINF 2008—First International Conference on Health Informatics. Madeira, Portugal: INSTICC Press.

Ramaprasad, A., Valenta, A., & Brooks, I. (2009). Clinical and translational science informatics: Translating information to transform health care. In L. Azevedo & A. R. Londral (Eds.), Proceedings of HEALTHINF 2009—Second International Conference on Health Informatics (pp. 135-141). Porto, Portugal: INSTICC Press.

Staab, S., Gómez-Pérez, A., Daelemana, W., Reinberger, M. L., & Noy, N. F. (2004). Why evaluate ontology technologies? Because it works! Intelligent Systems, IEEE, 19(4), 74-81.

Tufte, E.R. (1990) Envisioining Information, Cheshire, CT: Graphics Press.

Valenta, A. L., Brooks, I., Laureto, R. A., & Ramaprasad, A. (2007). Breaking the silo: Using informatics to support clinical and translational science. Journal of Health Information Management, 21(4), 15-17.

W3C. (2012). OWL 2 Web ontology language document overview (2nd Ed.). Retrieved May 2, 2013, from http://www.w3.org/TR/2012/REC-owl2-overview-20121211/

About the Authors

Arkalgud Ramaprasad is Professor Emeritus of Information and Decision Sciences at the University of Illinois at Chicago (UIC). His current research focus is on the using ontologies to for envision and realize large, complex systems—especially healthcare information systems. He has a PhD from the University of Pittsburgh, Pittsburgh, PA, 1980; MBA from the Indian Institute of Management, Ahmedabad, India, 1972; and BE (Electrical), from the University of Mysore, Karnataka, India, 1970. He speedwalks marathons and makes pizza from scratch.

Thant Syn is an Assistant Professor of Management Information Systems at the Texas A&M International University. He received his PhD from the Florida International University, MBA from the International University of Japan, and BE (Aeronautics) from the Yangon Technological University. His current research focuses on the development and application of ontology in healthcare informatics and other related fields